EXPERT SYSTEM OF RATIONAL DECISION MAKING OF DISTRIBUTION OF ELECTRIC IN BRANCHED ELECTRICAL NETWORK

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Abstract: *«Smart Grid» - is a large-scale direction in modern energy. This term is relatively recent: energy discontinues being just a facility of comfortable life; it becomes a facility of development of all directions of human activities. The significance of «Smart Grid» is to make generation; transmission and distribution of electrical energy «intelligent», to saturate electrical grids by modern facilities of diagnosis, by electronic control systems, by algorithms, by technical devices of short-circuit current limiters etc. The article offers the model of development of expert system based on the method of heuristics classification with the help of instrument called CLIPS, so it can become one of effective methods during solving the problem of consumption optimization in the system «Smart Grid».*

Keywords: *Smart Grid, expert system, CLIPS language, uncertainty, slots, sets of rules, decision-making, knowledge database, distribution of electricity, emergency situations, consumption, artificial intelligence.*

ACM Classification Keywords: *C.2.4 Distributed Systems, I.2 ARTIFICIAL INTELLIGENCE.*

Introduction

"Smart Grids"(intelligent grids) − are electrical grids, that satisfy the future demands of energy-efficient and economical functioning of energy system through the coordinated management and with the help of the modern bilateral communication between the elements of the electrical grids, electrical stations, accumulating devices and consumers. The development of the expert system model of the energy consumption can significantly improve the quality of the complicated system of the technical processes management; increase the quality of the problem solving and provide the economy of resources for account of effective distribution of the functions of the central control of local measurable and management subsystems. Such effect is achieved by openness of the system of knowledge representation about the object, adaptability of the system to the environment of functioning, and automatic correction of the management impacts during the parameters changes during the process of functioning.

CLIPS has been chosen as the instrumental tool for development of the expert system. The choice of CLIPS was made due to two reasons: first, this expert system developed by NASA, it has proved its efficiency and it is distributed freely over the Internet; secondly, the implementation of CLIPS in C + + allows transferring specific expert systems to various types of operating systems. It is also possible to work in real-time, when the response of the system must not exceed a few milliseconds.

The essence of work

Goals and objectives of our work:

Since the problem of energy economy in the future will become even more acute, we need a system that will track the spending of electricity to distribute it effectively. Therefore, we were given the task to develop the model of such system that has a knowledge base capable to self-improvement. Creating of expert system controlling energy consumption can significantly speed up the development of complex management systems, improve the quality of the problem solving and give the saving of resources through the function of efficient distribution of central management and local measuring and control subsystems. Rather, we only present the model of the expert system. This problem is very vast and deserves a serious future study.

Sphere of application:

1. Preventing the possible appearance of the emergency and crisis situations. The development of expert system allows taking into account the uncertainty of the system behavior and thus prevent the possible appearance of the emergency and crisis situations. In CLIPS language there is no direct way to consider uncertainty, but it's easy to include such tools in the program.

2. Performing the consideration of the system uncertainty by some combined or separately used methods.

3. Determination the priority of the rules significance. Different contradictions can appear during the management of the complicated system of the energy grid, to correct this, we can use "significance" (determining the priority of the rules) to execute the rules with the most authority first of all. Particular attention should be paid to the possibility of the optimization of management with the help of dividing expert knowledge from the management knowledge with the help of assigning different values to the rules of different phases.

4. Representation of combined reliability value. There is a possibility to put the information about the uncertainly directly to the facts and rules. It is done with the help of so called additional slots that represent the coefficient of reliability. For this purpose identical "threes" "object-attribute-value" are combined in one "three" that has combined value of reliability.

5. Minimizing the quantity of the used energy. If there is a multitude of generators producing energy and the multitude of devices consuming energy, then expert system can optimize it thus, to minimize the quantity of used generators and the amount of energy not consumed from every generator.

6. Termination of the work. It is possible to control the sensors data beyond the working and the allowable level and to determine all occurring with it trends. If the sensor readings are out of range, the appropriate device stops to work.

7. Analysis of the statistics. There is a statistic about the objects of the grid, about different parameters performance and grid security.

8. Structuring and editing of knowledge bases. The parts of the knowledge base are stored as the separate program modules and saved in different files to provide the convenience of structuring and editing knowledge bases of the large sizes.

Scientific novelty:

Our study demonstrates the implementation model of the expert system developed on Clips in the sphere of energy. We propose rational method of effective decision-making for suppliers and consumers of electricity in an extensive electric network, which differs from the existing methods by elements of self-learning executed by an expert system that reduces the cost of resources and time of decision-making.

The system has access to all existing data and knowledge bases, the system can learn, it can analyze the situations of uncertainty to make a conclusion (the fact) for itself, it can cultivate, accumulating experience. Then it makes decisions according to precedents using them as rules. So it is able to adapt to any environment.

Practical value:

The actuality of research is caused by the fact that the modern system of power moves to the new stage. The consumer becomes active. The consumer has the opportunity to generate energy and to participate in the power system in various ranges. Therefore, the development of intelligent grids is actual. The main areas of application of expert systems are management, interpretation, forecasting, planning, monitoring and training. Use of expert systems in the field of production and consumption of electric energy helps to avoid many mistakes during decision making and thereby increase profits or save resources. In addition, the use of these systems in the planning activities of enterprises and predicting makes it possible to avoid unnecessary losses.

Applied expert systems in the sphere of energy today:

As a result of the analysis, we found that nowadays neural networks, algorithms of the focused sorting, genetic algorithms, statistical methods, fuzzy logic, methods of support vectors, the methods of the end user, the methods of the same day, optimization methods, systems of the situation management etc. are used in the field of energy. The expert system based on production rules can be one of the analytical methods. CLIPS has been chosen as an effective tool for developing of such expert system, since it can deal with a crisp, fuzzy (or imprecise), and combined reasoning. It allows mixing freely fuzzy and normal conditions in the rules and facts of expert system.

The proposed method of analyses:

The following model of electric grid system (presented on the fig. 1 bellow) is proposed. It describes the process of interaction of developed expert system with other blocks of the “Smart Grid”. These blocks, unioned in one platform, allow a new approach to the construction of electrical grids, conversing from the strict structure “generation-grids-consumer” to more flexible system, where every unit of the grid can be an active element. At the same time intelligent grid in automatic mode executes reconfiguration, if the conditions change.

To automate the process of decision-making with the help of an expert system we should programmatically implement the domain model. For this purpose, frame-based structure and generating rules are very usable. The developed system is an expert system of production type and consists of the user interface, working memory, knowledge base and inference machine. Ontology optimization of electrical networks is used for knowledge representation in the system, it contains concepts (terms) and relationships, which contain the expert knowledge about the object field. Working memory stores the associated relationship instances of the ontology describing the qualitative and mathematical models. The knowledge database contains the operational knowledge of the subject area, expressed in terms of ontology and organized in the form of production rules.

Language CLIPS is based on rules and allows to present knowledge in the form of sentences like "if (condition), then (action)". By “condition” is meant some sample sentence, according to which the search in the knowledge base will be done, and by “action” is meant action that is performed in case of the successful result of the search.

CLIPS uses the productive model of knowledge representation and therefore contains three main elements: a list of facts; base rules; output block.

The base of facts and rules have the following functions: database of facts represents the initial state of the problem, the rules base contains operators that transform the state of the problem, leading to its decision.

In systems based on the knowledge, the part of the program (the knowledge base), that contains a representation of knowledge concerning a particular subjects, is usually separated from the program part that deals with the formulation of reasons (the logical machine).

This separation allows to make changes (of course within reason) in one part of the program without changing the other. In particular, we can add new information to the knowledge base, expand the available knowledge in the system, or adjust logical mechanism, increasing its efficiency, not modifing system code, and that is a significant advantage.

So it is much easier to use CLIPS, than traditional programming languages, because CLIPS has the logical machine that matches the facts and certain rules and finds what rules can be activated.

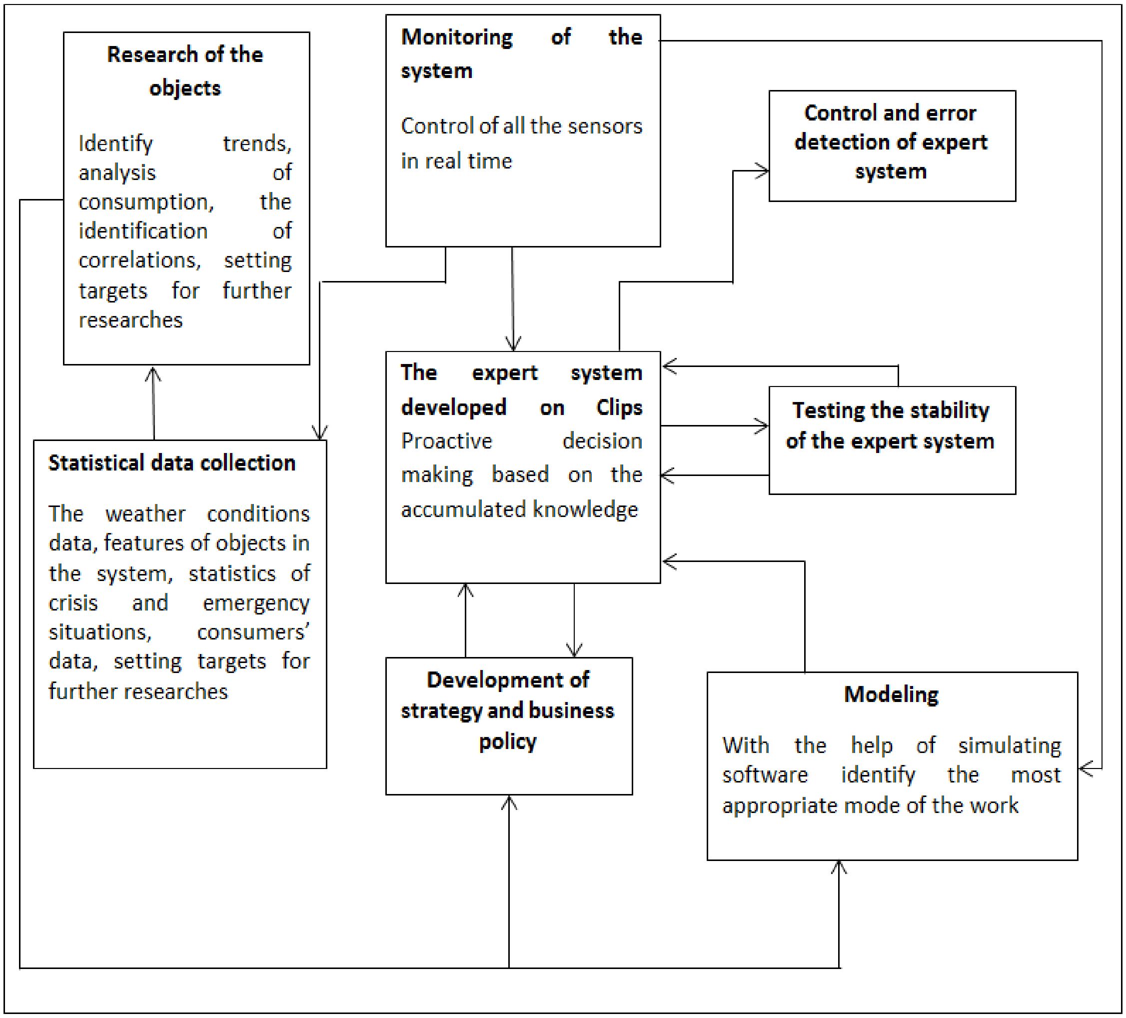

Figure 1. Model of electric grid system.

The fragment of the program prototype, that displays the relevant ideas, was implemented. It determines the optimal state of the network (grid state), a software prototype is aligned to achieve a certain goal (we can see it on the following figure Fig. 2).

This fragment of code defines a state in which a particular device should work. Logical inference of the grid status is executed with the help of search of attribute “goal”.

```
(defrule propagate-goal "" // template of the rule that retrieves the goal value
  (goal is ?goal)
(rule (if ?variable $?) // if the variable fulfills the conditions
then ?goal ? ?value))
=> (assert (goal is ?variable))) // assert variable as goal
(defrule goal-satified ""  // template of the rule if the goal achieved
(declare (salience 30)) // identificatie the importance of the of rule
?f <- (goal is ?goal) // designate the variable f goal value
(variable ?goal ?value) // designate the goal variable value
```

```
(answer ? ?text ?goal) =>  (retract ?f) // interacting with the decision making person
```

The knowledge base in this example is a collection of facts which represent backward chaining rules. It takes into account the optimum voltage at which the device can be operated, readiness of the device, the price of the real-time and other factors.

```
(deffacts knowledge-base
(goal is grid.state) //declare grid.state as the curent goal
(rule (if device.1 is yes and price is "less than 100") // if device1 is ready and real-time price is suitable
(then grid.state is "switch_on_the_device_1")) // then switch on device1
```

Bellow we can see the the fragment of dialog of the expert system with the decision making person. But in implemented expert system model, automatic reading of sensor data is proposed.

```
(question price is "What is the price?"  // interaction with the decision-making person
ANSWERS "1.less than 100" "2.more than 100" LEGALS 1 2) //legal values of the answers
(question voltage is "What is the voltage?"
ANSWERS "1.between 160 W and 240 W" "2.less than 160 W" "3.more than 240 W" LEGALS 1 2 3)
(answer is "You should probably use " " grid.state)) // goal is achieved
```

Let's learn more detail the fragments of the expert system prototype. There is a database derived from the sensors. This data is normed.

The rules are executed on the basis of database of precedents. After the current case is handled by an expert, it is entered into the precedent database, together with its decision for possible future use.

The filling of the precedent database can be executed either before the beginning of management process on the base of prior information, with the help of real or modeled precedents, or during the process of management, after the resulting output of management impact.

Sensor data, that controls the operations of certain devices, is received at the entrance of the expert system. The expert system converts this data into the facts. Then the conflict resolution mechanism, defining the importance of the rule, is used for the rules.

Also, for the execution of rules in the correct order, an approach of the work of an expert system in different modules is proposed, to divide the management knowledge from the knowledge in the subject field. For this purpose, the template, showing the mode where this rule is generally applicable, is used.

After that management rules, transmitting control between the various modules, are formed. Bellow we can see the example of the rule switching between the normal work of the grid to the mode of the emergency.

```
(defrule normal_mode-to-emergency_mode // switch to the phase of an emergency
(declare (salience-10))  // declare the salience
?phase<-(normal_mode) // extract the current phase of work
=>
retract(phase)  //  retract the current phase
assert phase (emergency_mode) // assert the phase of the emergency
```

In order to identify trends that could lead to emergency situations in the grid we use the command called Matches that determines the number of partial activations of the rules.

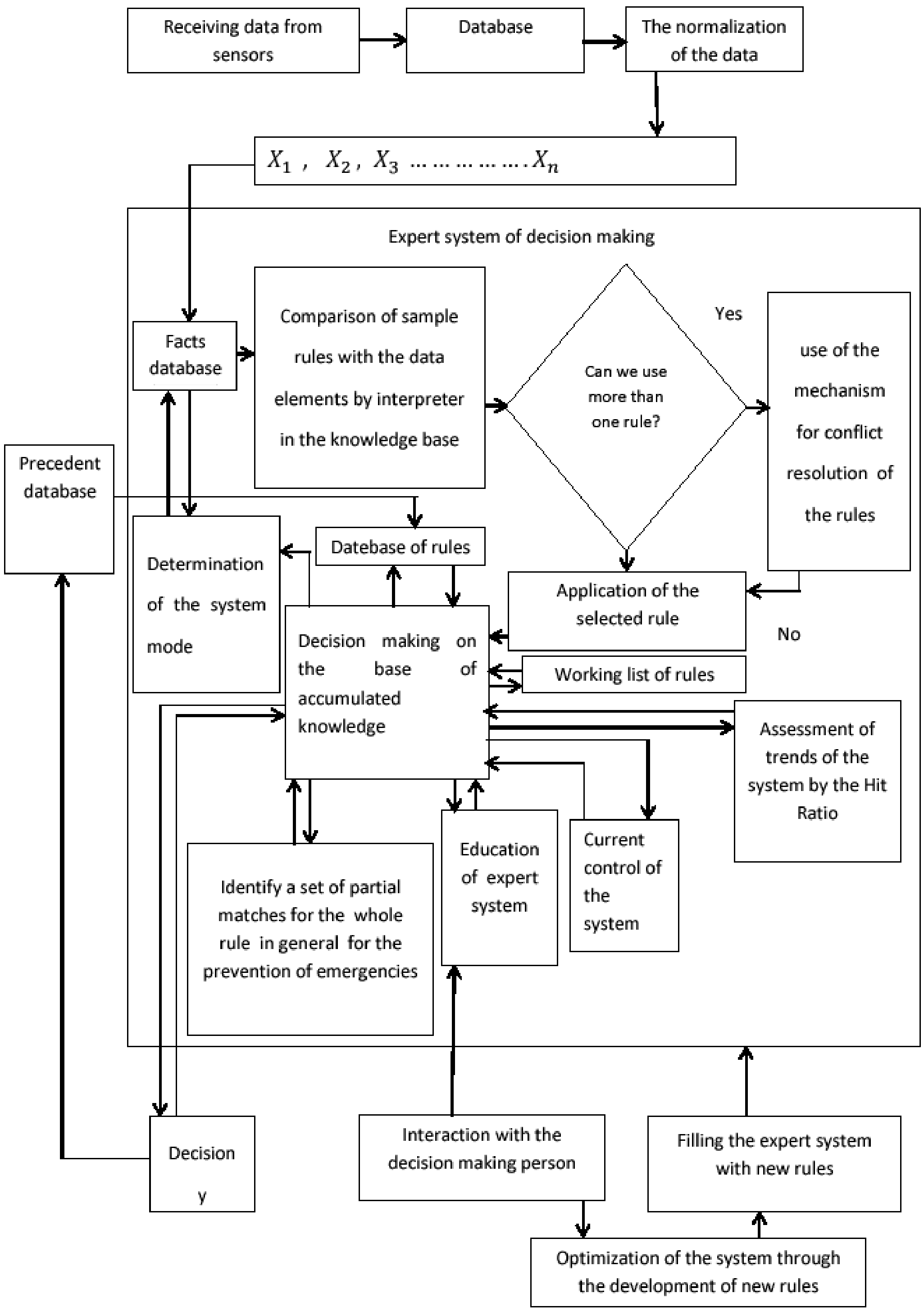

Figure 2. The fragment of the program prototype

Evaluation of trends of the network can also be accomplished with the use of parameter HitRatio, which can be described as follows. Let $\{x^1, x^2, ...x^n\} \in X$ be the set of incoming facts and $\{y^1, y^2, ...y^n\} \in Y$ are defining symptoms of emergencies.

$$Compute - Hit\ Ratio\,(X, Y)$$

$$for\, i \leftarrow 1\ to\ length[X]$$

$$if\ X^{i} \in Y$$

$$hits \leftarrow hits + 1$$

$$hitratio \leftarrow \left(\frac{hits}{length[Y]}\right) \cdot 100$$

Thus, we can determine the percentage amount of danger symptoms.

For better display of the real grid state the rules with several templates are used, that allows to execute classification and systematization of the observable facts.

```
(deftemplate grid-system  // create a template fact called grid-system
(slot type) // create a template slot of grid-system
(slot status)) // create a template slot t of grid-system
(defrule class-A-flood)) // if the grid state is on
(grid-system (type)  // if the grid state is on
(status on))    // check the current status
=>
(print out t “Shut down electrical equipment” crlf)) // Shut down electrical equipment
```

The algorithm “Solve_Tree_and_Learn” is used for learning of the expert system, where every unit of the decision making tree is represented in the view of facts. During the sweep through the rules of "replace-answer-node" the question of how to identify this situation is formed. Old unit for this node is replaced by the decision-making unit and by two new question nodes, to answer once again the question mastered as a result of training.

Functioning of some devices in the grid depends on the normal work of other devices. Each device has a sensor that displays the status of the device. Each cycle of the current control consists of three phases. During the first phase the values of sensors are read, at the second phase sensor values are analyzed, and at the third phase all required actions are executed (issuing of warning messages, stops of the devices work are determined by the output of sensors from the limit of permissible states etc.)

As a result, the expert system generates a solution, and the output document with all features about the done decision is formed for the decision making person.

Conclusion

Energy consumption certainly depends not only on the work of power station, but also on the correct architecture, management of memory and of peripheral devices. The idea of implementation of the expert system of the Clips type can bring new results in the field of cost-saving energy consumption and energy distribution in the Smart Grid.

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